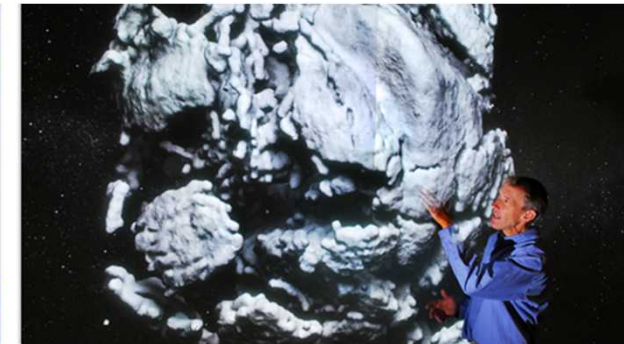


Exceptional service in the national interest



SIRFN Update on Advanced Inverter Interoperability Testing

9 Sept, 2015

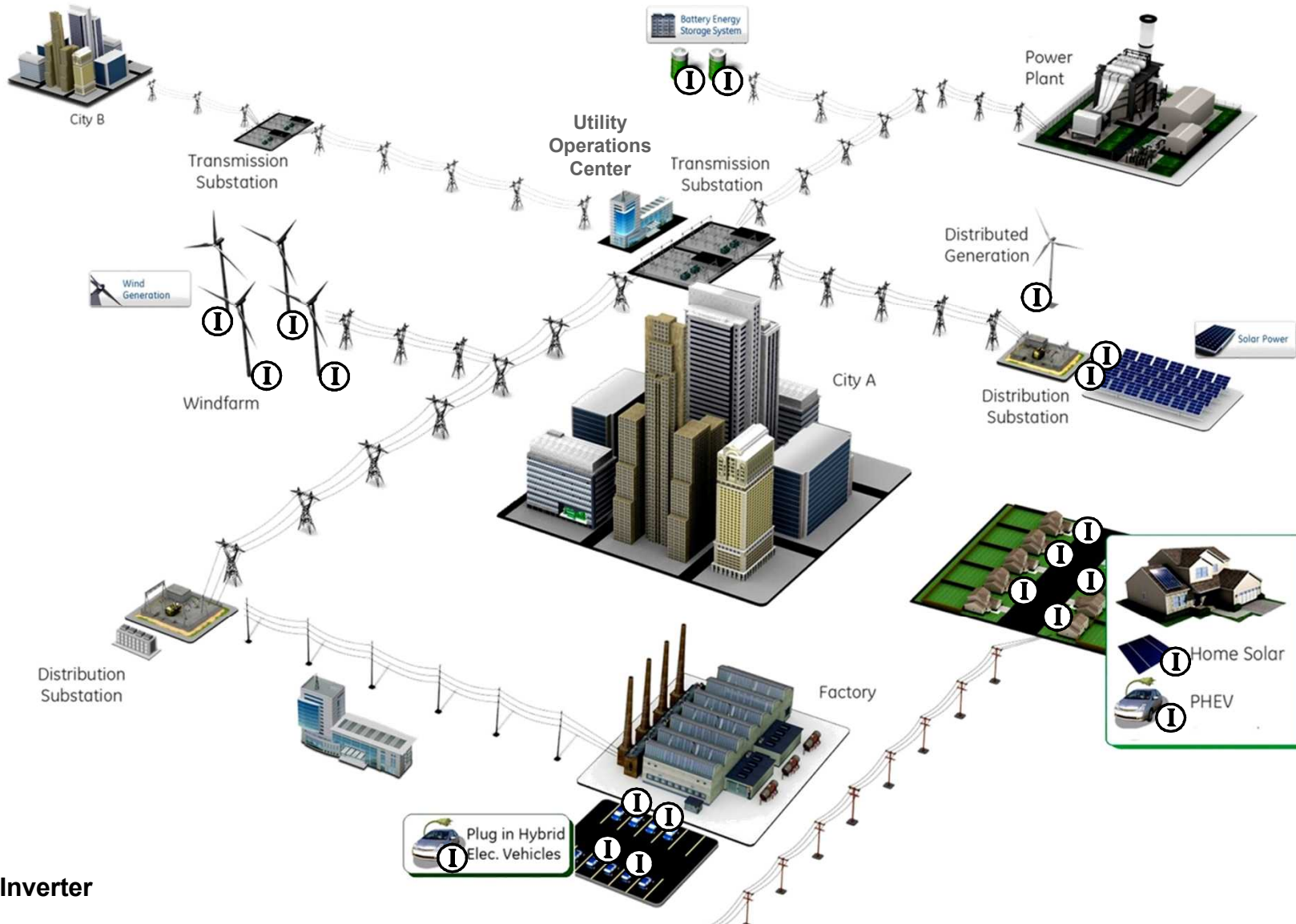
Jay Johnson

Sandia National Laboratories

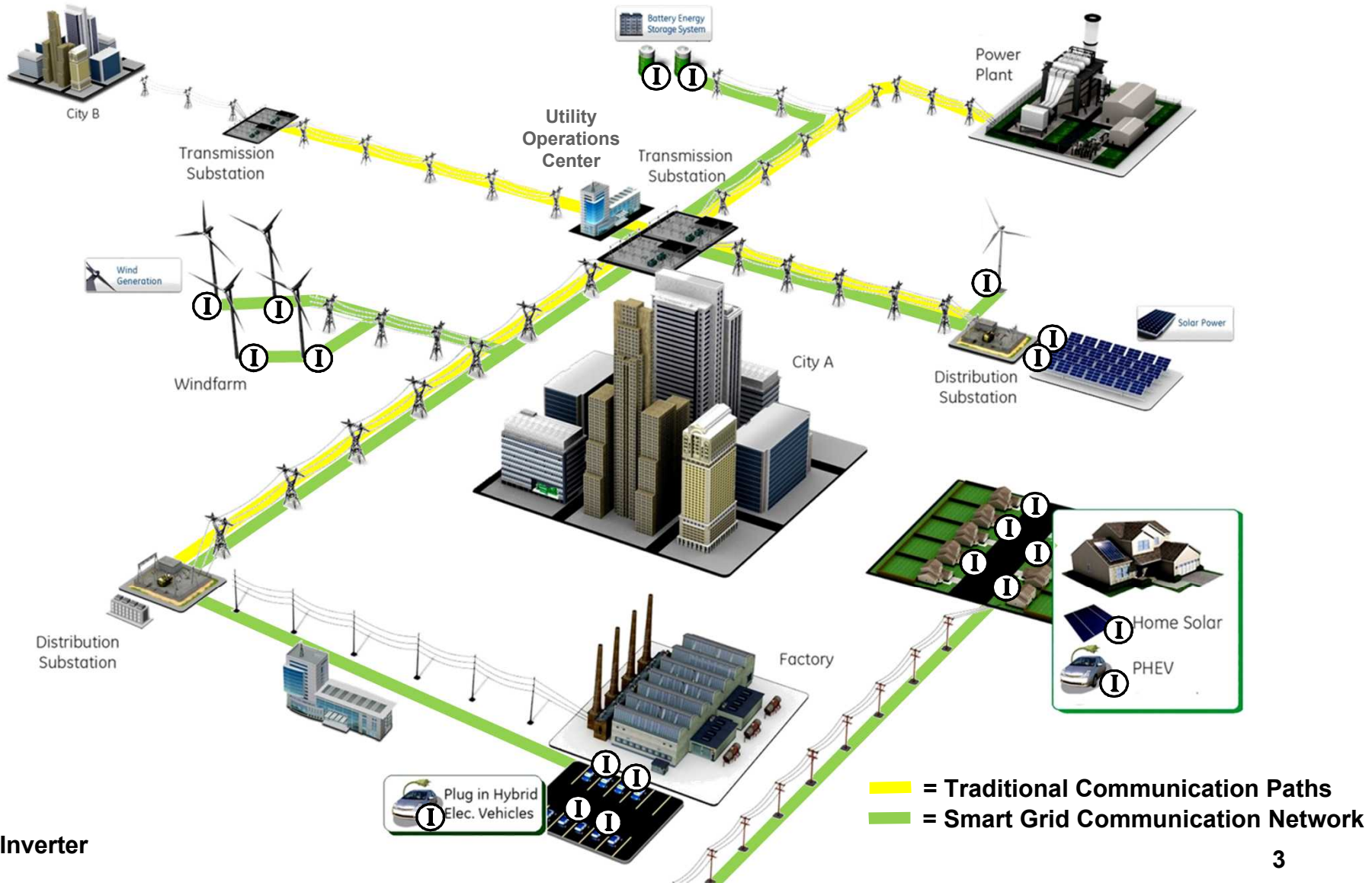


Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

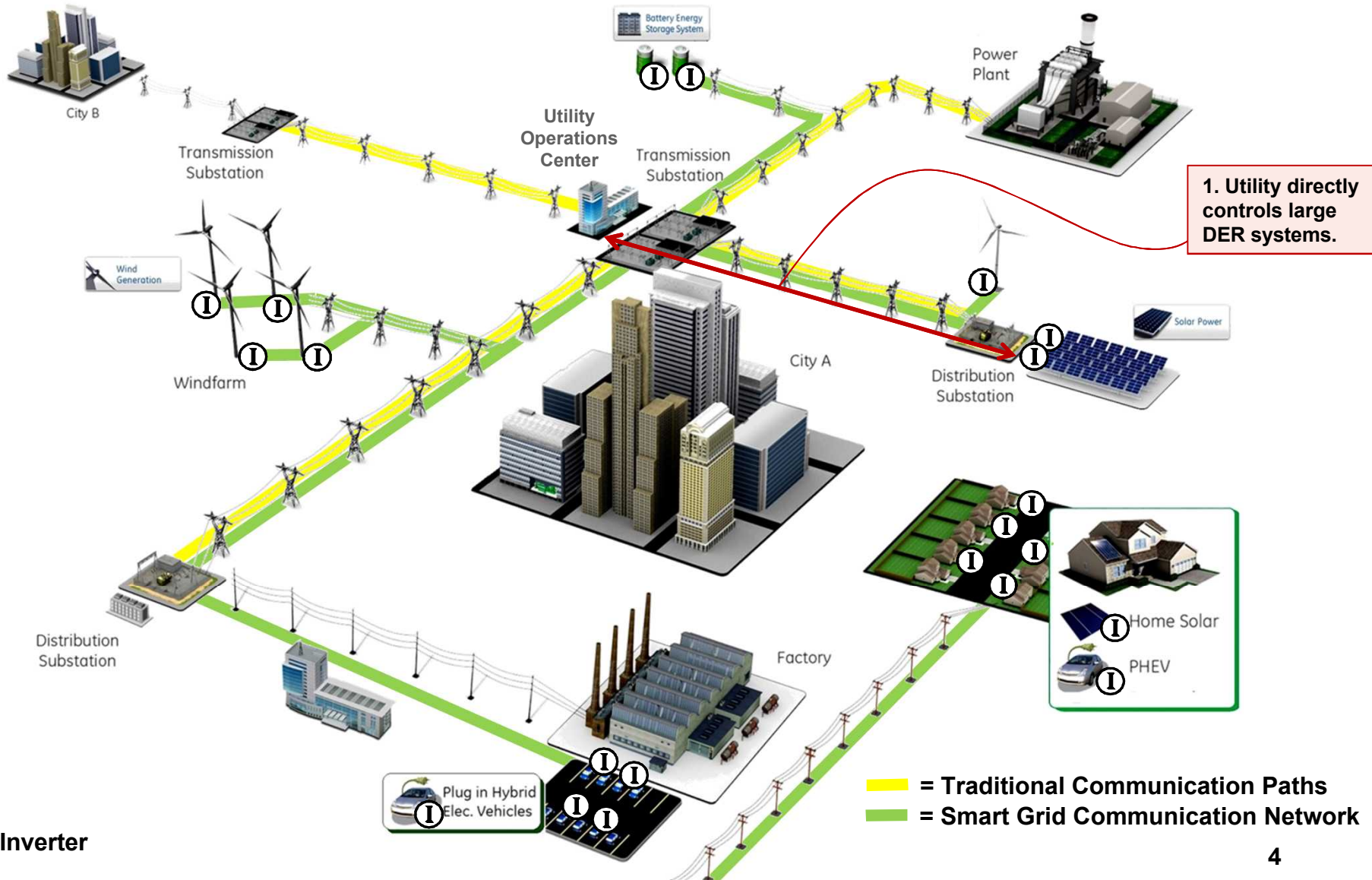
Smart Electricity Grid



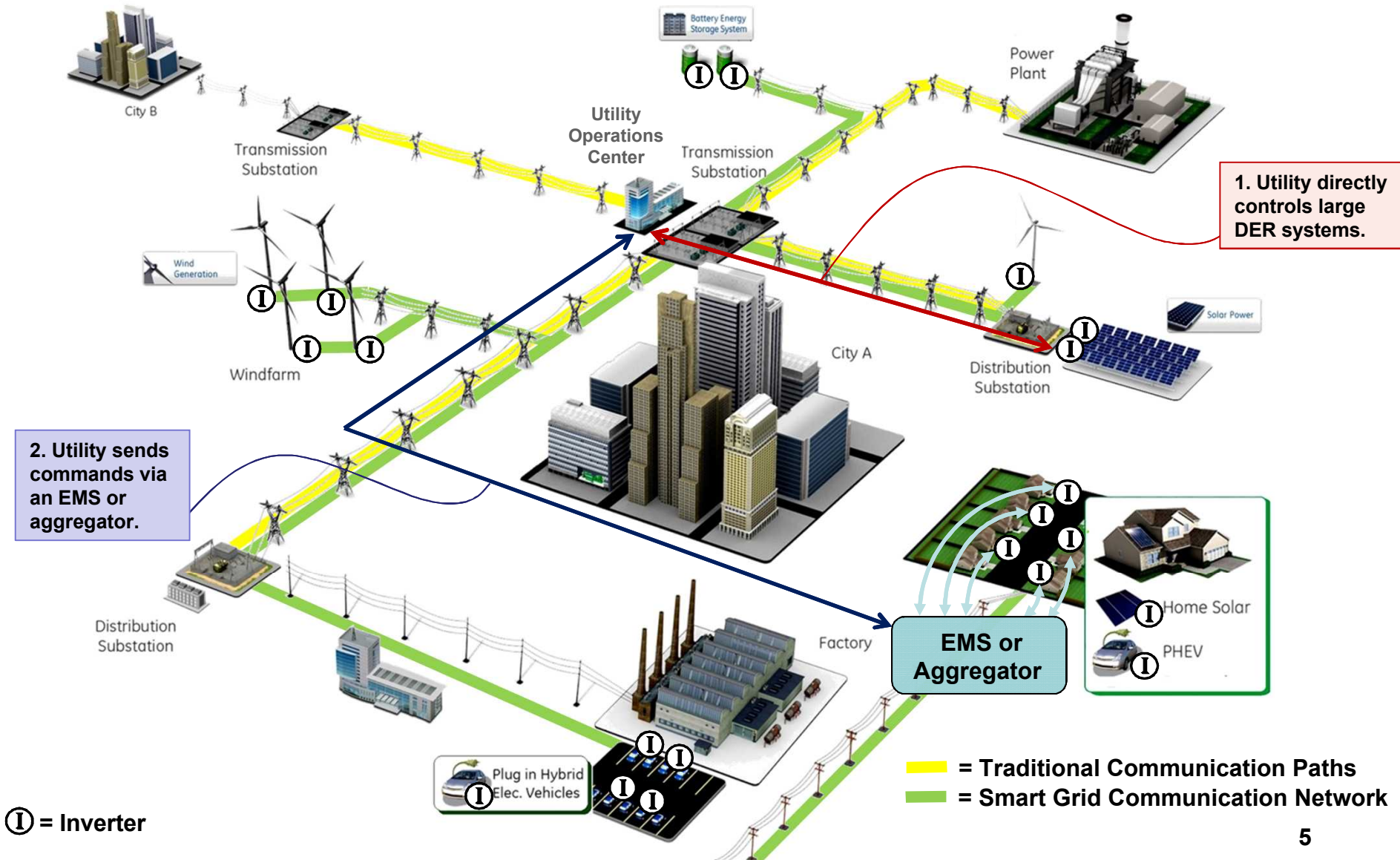
Smart Electricity Grid Communications



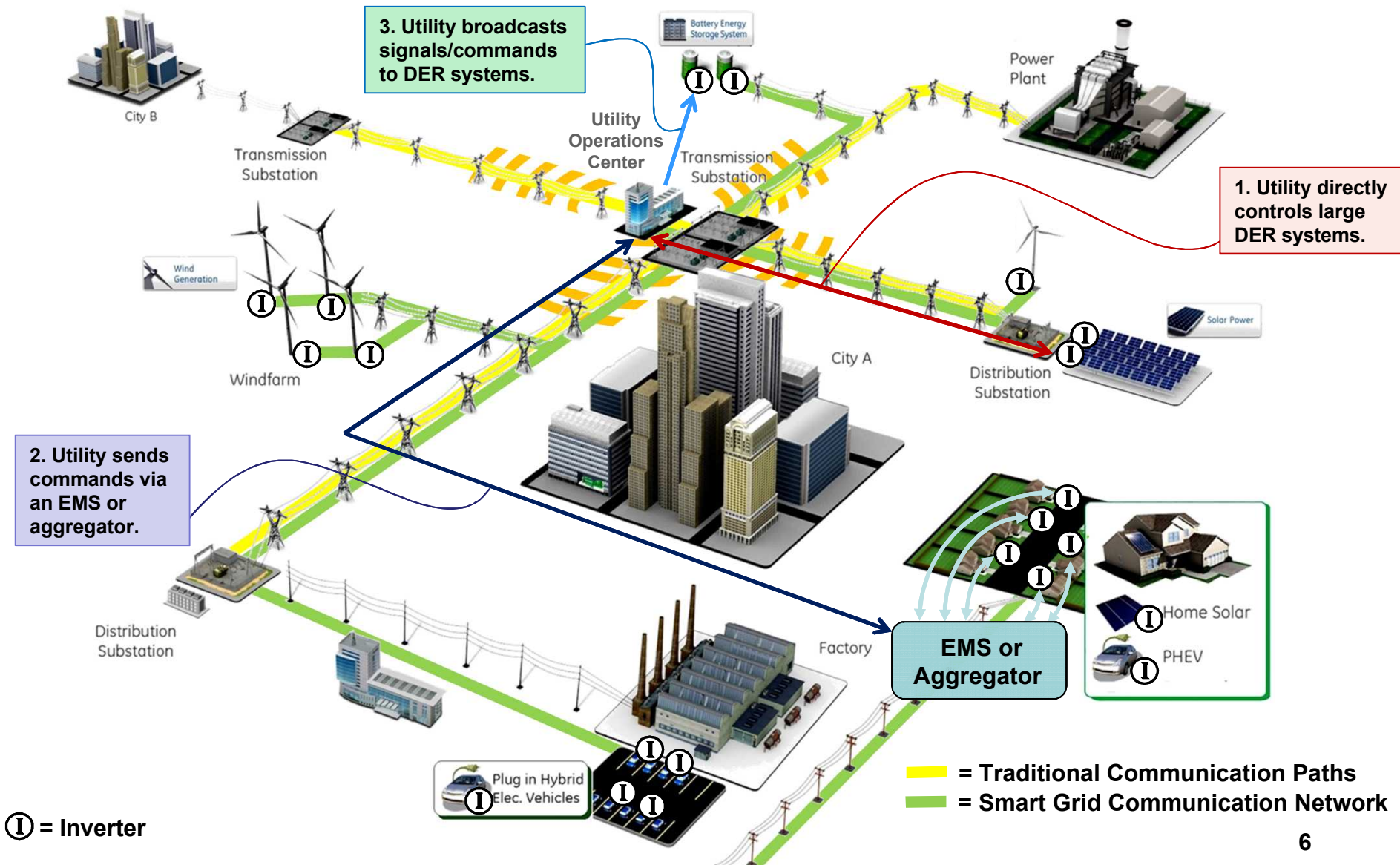
Smart Electricity Grid Communications



Smart Electricity Grid Communications

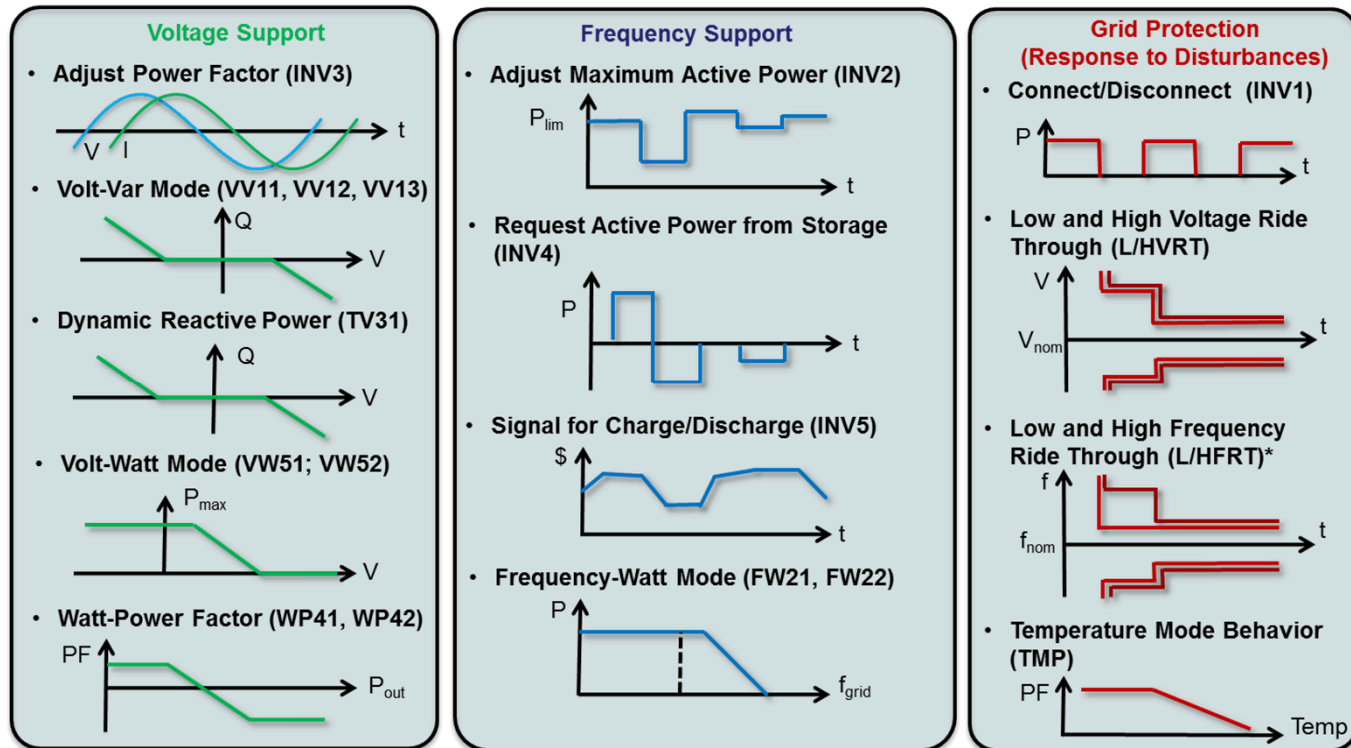


Smart Electricity Grid Communications



Advanced Interoperability Functions

- New 'smart' inverters will include multiple advanced functions
 - Autonomous: Inverter response to local voltage and frequency conditions
 - Commanded: Remote control (e.g., on/off, set power factor)
- Utilities will modify distributed energy resource (DER) behavior using communications. Reliable interoperability will be required.



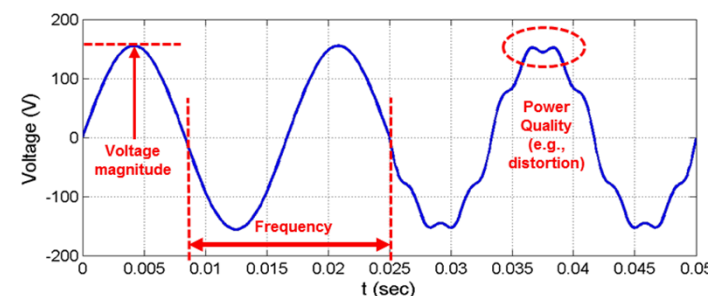
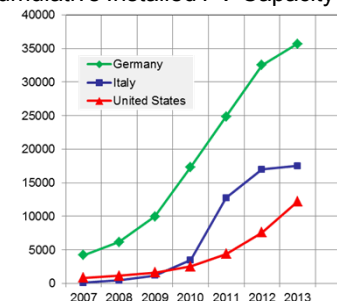
Advanced functions as defined in IEC TR 61850-90-7.

*FRT not included in IEC 61850-90-7, but is in Sandia Test Protocols.

Importance of SIRFN Collaboration

- **SIRFN collaboration is helping accelerate the deployment of renewable energy in the US and rest of the world**
 - Higher renewable energy penetrations
→ grid voltage and frequency stability concerns
 - Inverters must now support/stabilize the grid
- **Urgency in U.S. to certify inverters for new requirements** – both electrical performance and communications
 - Need advanced inverter test protocols for CPUC Electric Rule 21
 - Sandia protocols act as basis for updates to UL 1741
- **Goal:** develop a robust consensus certification procedure for advanced inverter functions for adoption by international standards organizations

Cumulative Installed PV Capacity (MW)



Sandia-KERI Smart Grid Collaboration

- 3-year project started in 2013 (paralleling the SIRFN project)
 - **Primary goal:** develop and demonstrate a consensus-based testing standard for the interoperability of Distributed Energy Resource (DER) devices.
 - Design and construct advanced interoperability test-beds at SNL and KERI.
 - Standardize advanced function testing of PV inverters and energy storage systems.
 - Compare test results, communications methods, and automation procedures.



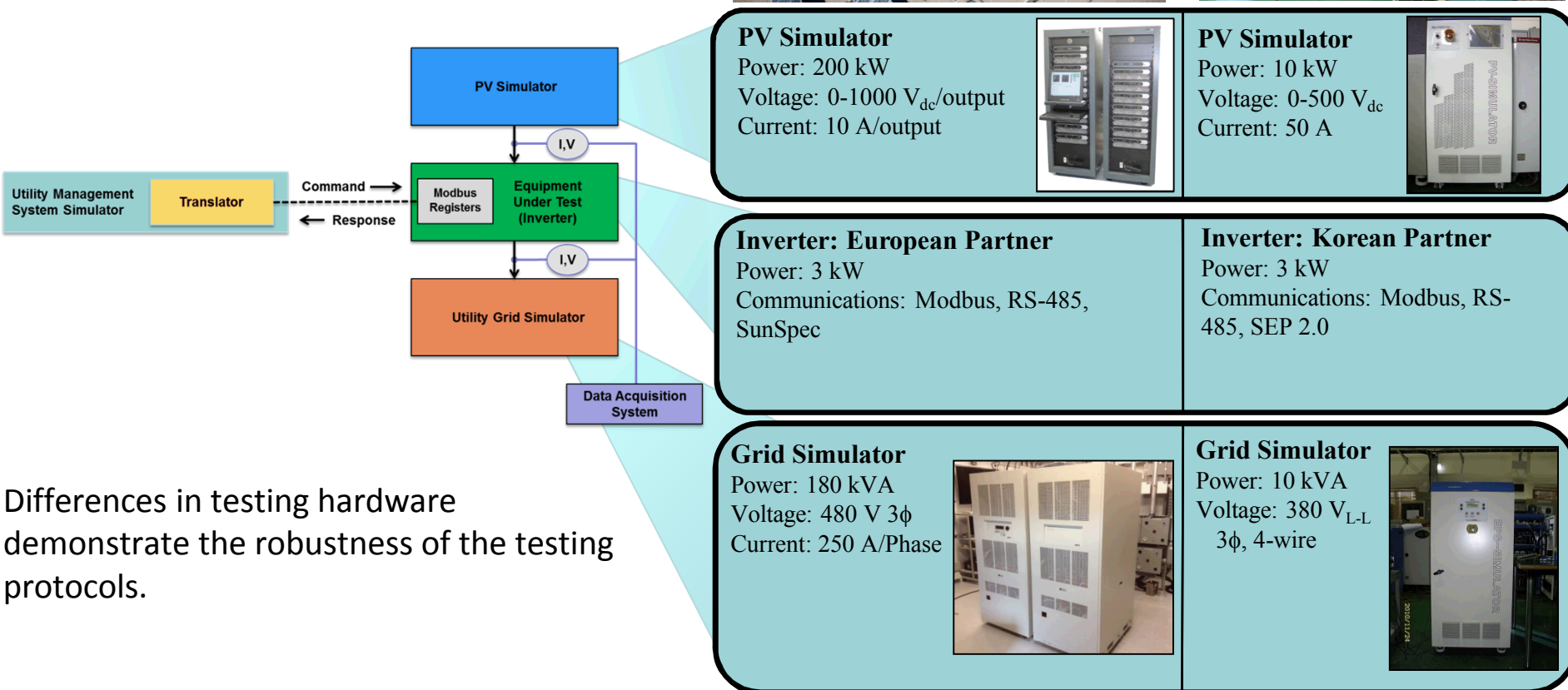
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Korea Electrotechnology
Research Institute

Sandia and KERI Test-Bed Hardware Comparison

Both Sandia and KERI have built advanced inverter test-beds. These facilities are running inverter tests in parallel. As difficulties are identified, both partners collaborate to address the issues.

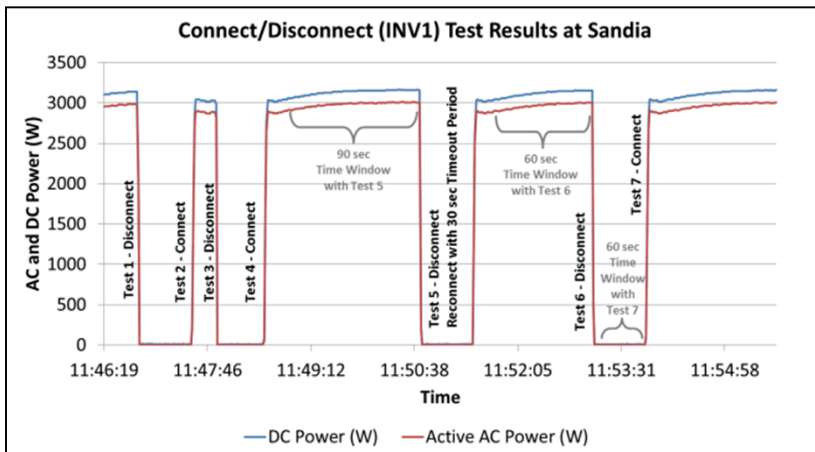


Test Protocol Development

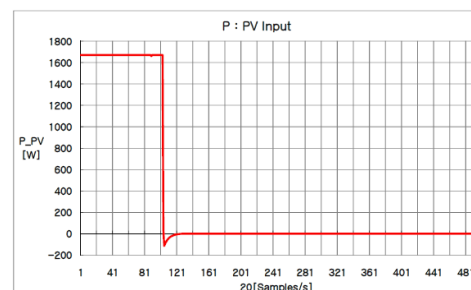
- The Sandia Test Protocols were the basis for the tests.
 - Based on the limitations of test hardware, only some AGFs were tested by both laboratories:
 - INV1: Connect/Disconnect
 - INV2: Active Power Curtailment
 - INV3: Fixed Power factor

#	EUT Initial Operating State	Command	Time Window (sec)	Timeout Period (sec)
1	>50% rated power, unity power factor	Disconnect	0	Default (e.g., 0)
2	Inverter off	Connect	0	Default (e.g., 0)
3	>50% rated power, unity power factor	Disconnect	90	30
4	>50% rated power, unity power factor	Disconnect	60	0 (No Timeout)
5	Inverter off	Connect	60	0 (No Timeout)

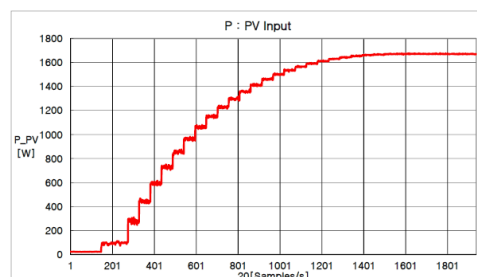
INV1 Test Matrix



Sandia INV1, Tests 1-7



KERI INV1, Test 1



KERI INV1, Test 2

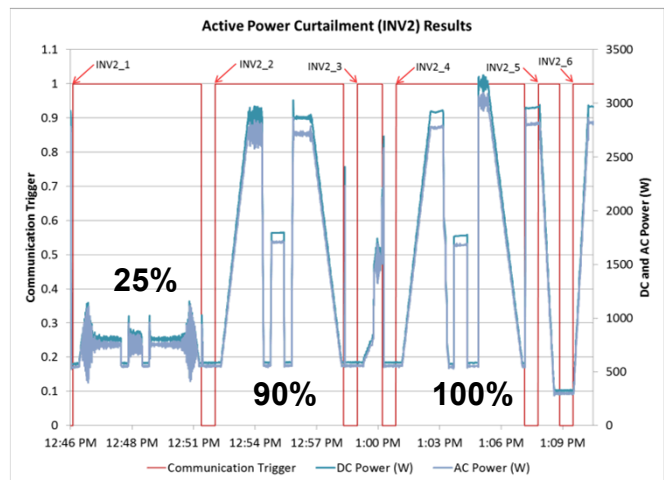


Sandia Test Protocols

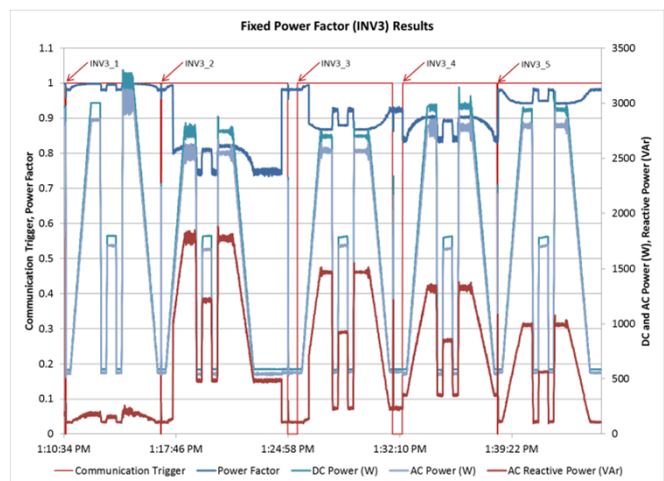
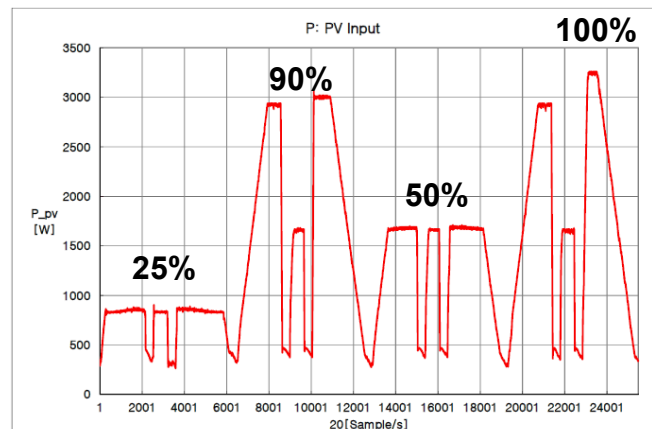
J. Johnson S. Gonzalez, M.E. Ralph, A. Ellis, and R. Broderick, "Test Protocols for Advanced Inverter Interoperability Functions - Appendices," Sandia Technical Report SAND2013-9875, Nov. 2013.

INV2 and INV3 Results

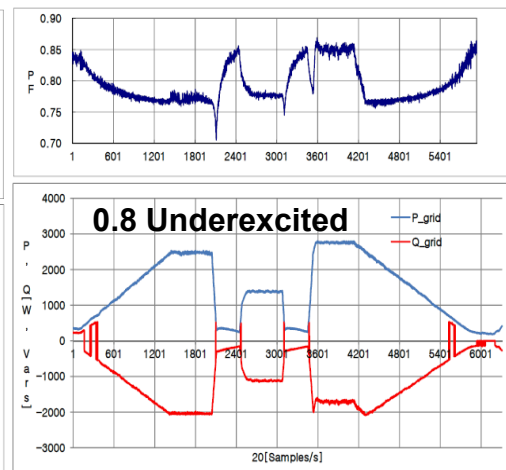
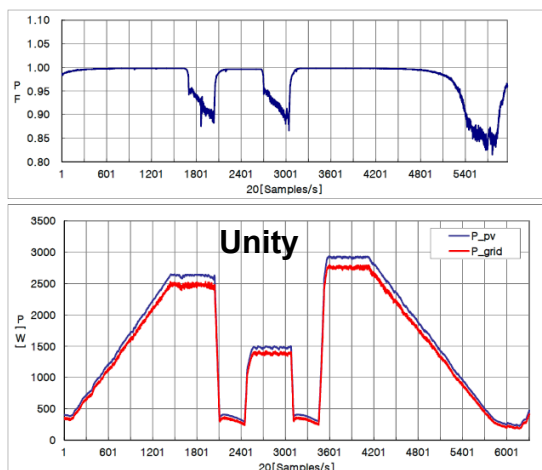
Sandia Test Results



KERI Test Results

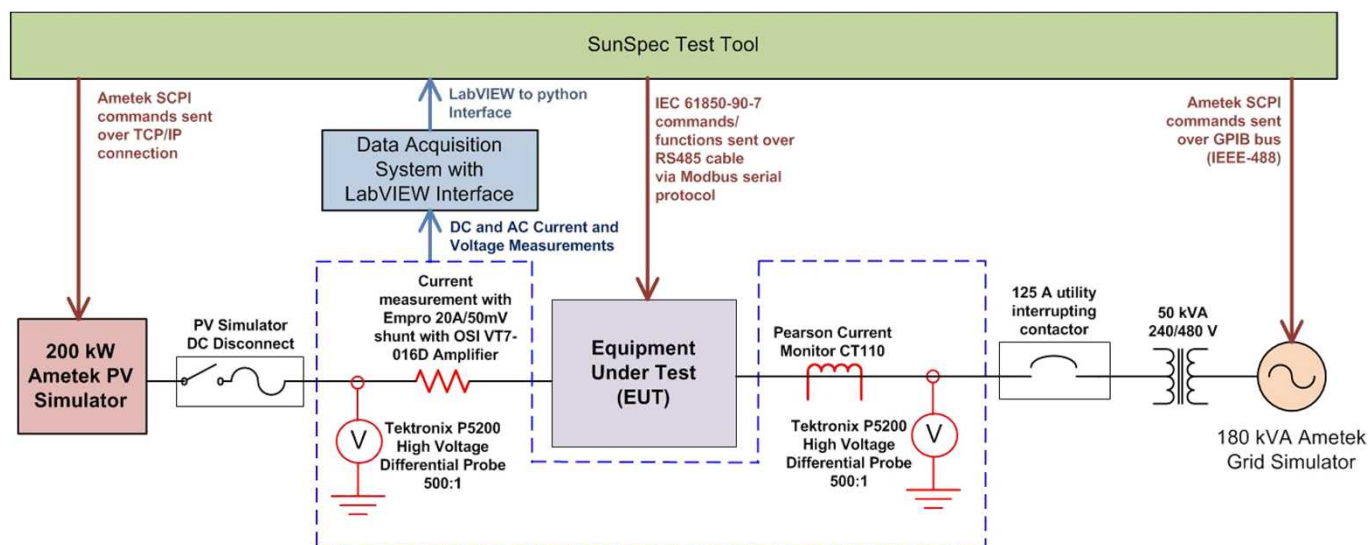


Fixed Power Factor Tests



Program Impact

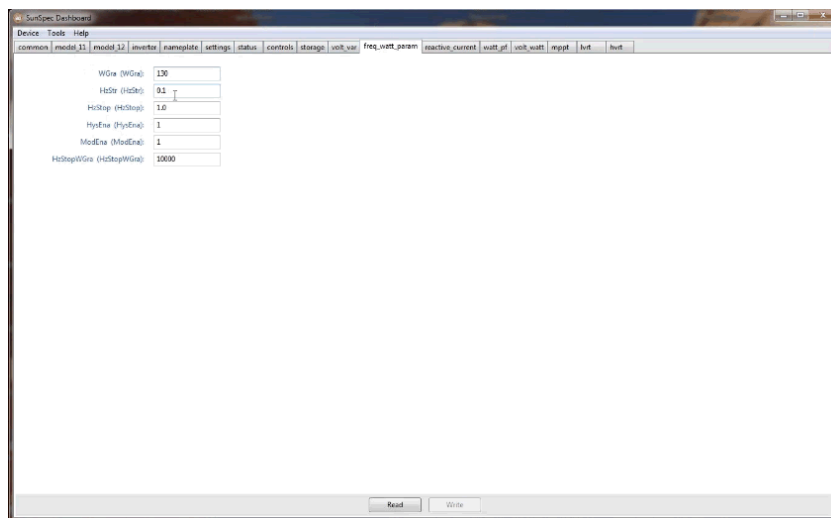
- The research project has made impact!
 - The refined test protocols for the project have acted as **the basis** for the new testing requirements in the United States known as **UL 1741 Supplement A**.
 - As part of the project, Sandia has worked with the **SunSpec Alliance** to create an automated **System Validation Platform (SVP)**.
 - This software allows test scripts to be passed between laboratories.
 - KERI and Sandia have copies of the software program.
 - Underwriters Laboratories is investigating the SVP for certification testing



SunSpec Alliance Tools

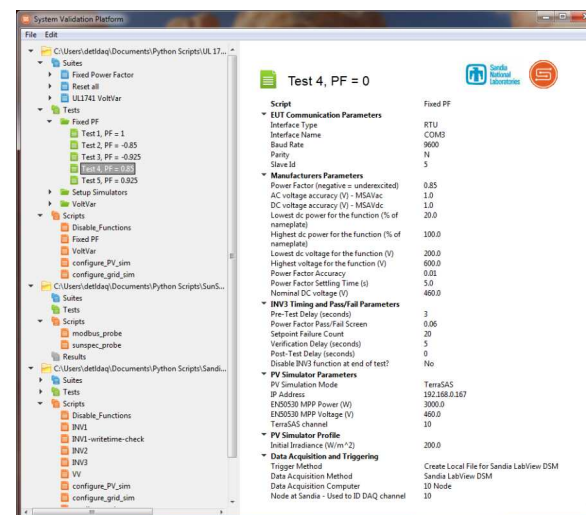
■ Dashboard

- Reads the SunSpec models of the EUT
- Simple read/write functionality
- Free for SunSpec members
- Download here:
<http://sunspec.org/sunspec-dashboard/>



■ System Validation Platform

- Scripting capabilities
- Full automation is possible
- Currently being sold to manufacturers and labs at \$15k/license
- Download here:
<http://sunspec.org/sunspec-svp/>



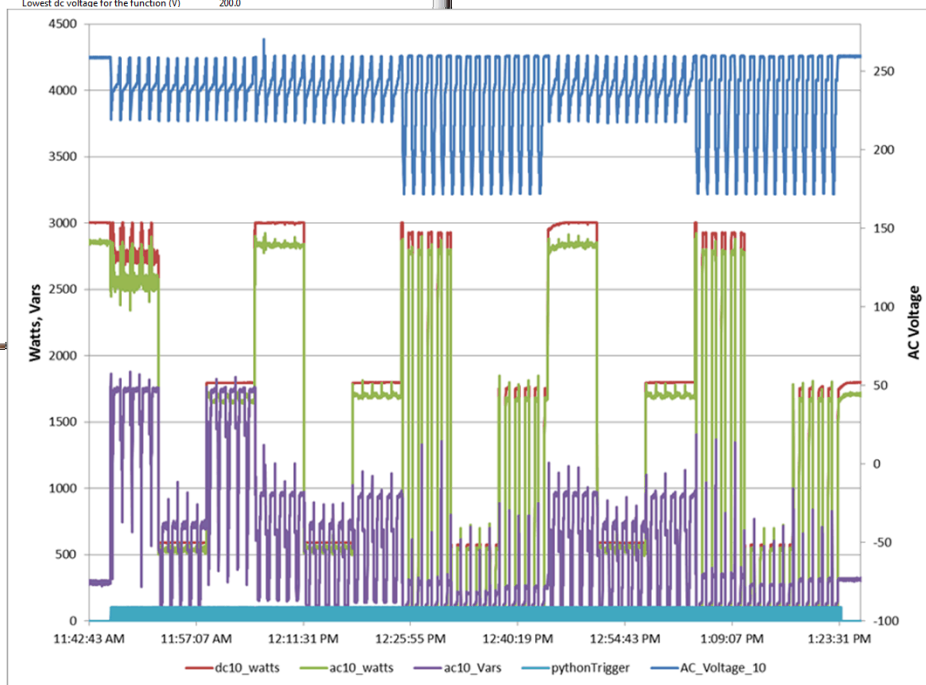
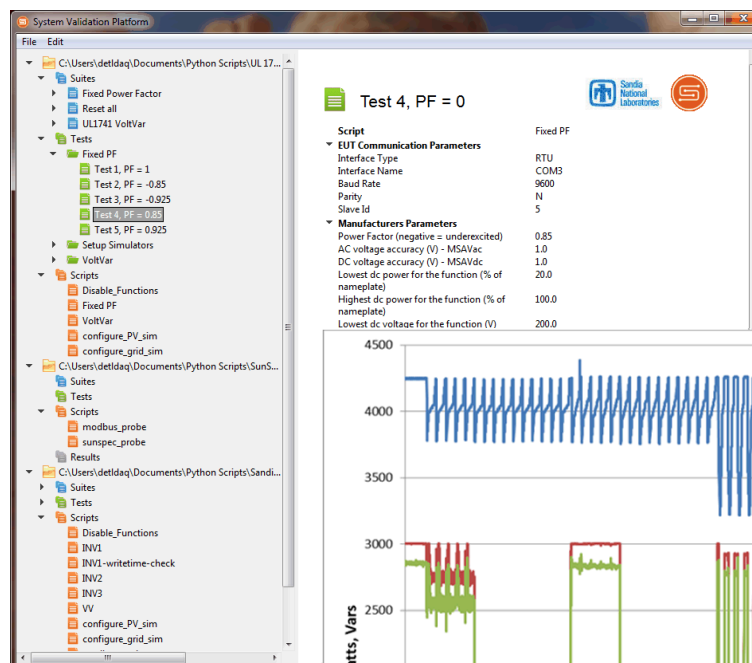
SIRFN SVP Licensing

- August 28th, 2015 Sandia extended the contract with SunSpec Alliance to develop the SVP GUI.
- To accelerate adoption, Sandia and SunSpec agreed to create the following SVP group license for SIRFN members:
 - License term is for a period of **two years**
 - Each partner (“Technalia, AIT, RSE, FREA, Fraunhofer IWES, DNV GL, CPRI, and other SIRFN member labs”) may install the software on **two computers** each
 - Also included are: 1) phone and **email support** with a 24 hour response guarantee, 2) **remote installation support** at each site, and 3) four hours of **end user application and script development training** (delivered over the web).
 - Services related to integrating SunSpec SVP with PV simulators, load simulators, historians, and other software orchestration products are not included. If you and your partners require such services, SunSpec is happy to provide them under **separate contract**.

I would like SIRFN to work closely with Bob Fox (bob@sunspec.org) to improve the SVP and make it the worldwide standard for interoperability testing and certification!

SunSpec/Sandia System Validation Platform

- System Validation Platform (SVP) is an automated certification interoperability platform
 - Fully scriptable
 - Interacts with DAQs, PV and grid simulators and SunSpec-compliant DER.

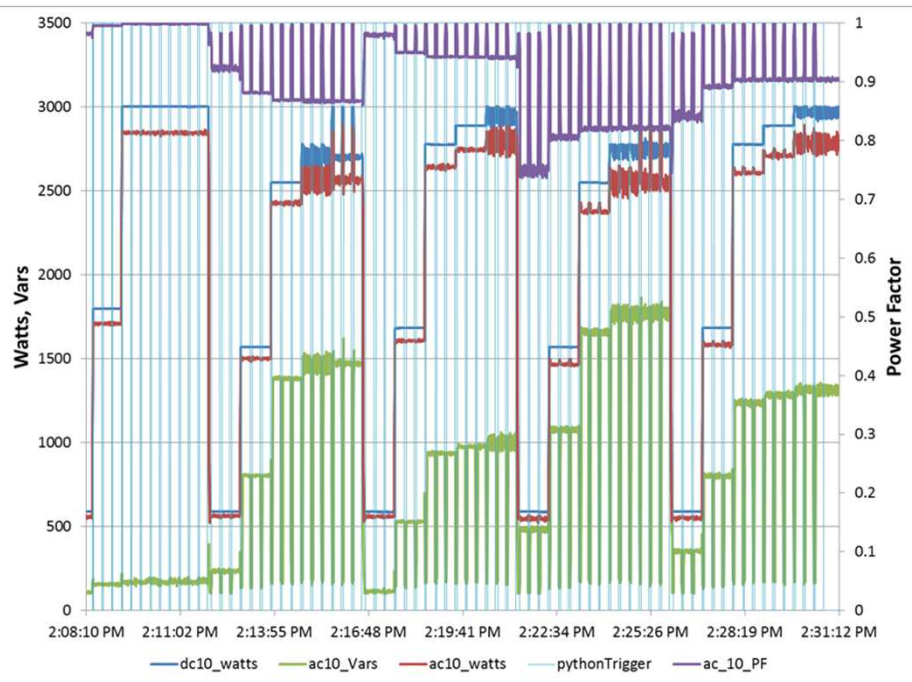


Automated UL 1741 SA volt-var tests. 375 measurement points.

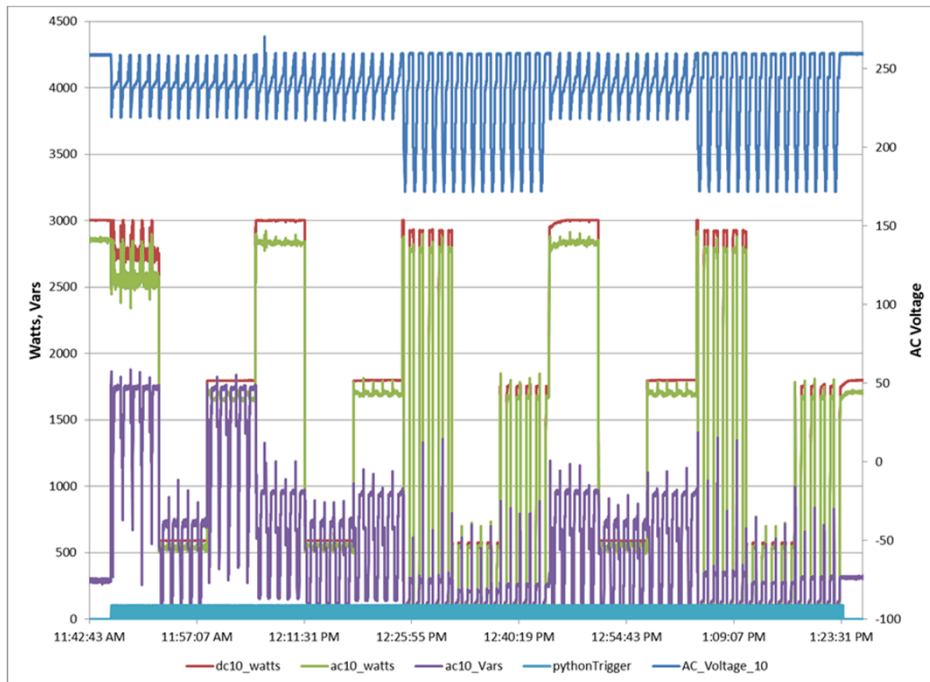
Power of Testing Automation

- UL 1741 SA test permutations are large due to the number of settings in each advanced DER function:
 - 75 measurements for fixed power factor - takes about 25 minutes with the SVP
 - 375 measurements for volt/var - takes about 90 minutes with the SVP

Proposed UL 1741 SA fixed power factor tests.



Proposed UL 1741 SA volt-var tests.



SVP Script Status

- Sandia Test Protocols for IEC 61850-90-7
 - INV1 (Connect/disconnect)
 - INV2 (Curtail active power)
 - INV3 (Fixed power factor)
 - VV12 (Volt-var with reactive power priority)
 - VV11, VV13, VV14 (**untested**)
 - FW21 (parameters – **debugging screening**) and FW22 (pointwise - **untested**)
 - VRT (voltage ride through, **incomplete**)
- UL 1741 SA
 - Fixed Power
 - Volt-var
- General scripts
 - Disable functions
 - Configure Ametek grid simulator
 - Configure Ametek PV simulator

- SIRFN Webinar Automation of Advanced DER Testing
 - Presented July 16, 2015
 - 80 minutes long webinar located on Basecamp
 - Shows basic operation of the two SunSpec tools
 - Will be helpful for getting other SIRFN labs caught up

- Note: SVP can be used with different hardware systems (simulators and data acquisition systems) and will no longer require the EUT to be SunSpec-compliant in the next version of the software.

Conclusions

- PV inverter **advanced functions help support the electricity grid.**
- **Standardized test methods** for verifying **DER functionality** and **interoperability** are **critical**.
 - In the U.S., many **jurisdictions** are **considering smart DER requirements**
- **Sandia, KERI, and SIRFN are improving certification protocols** by:
 - Building test-beds for advanced inverter testing (electrical performance and interoperability).
 - Comparing advanced DER test results and improving draft certification protocols.
 - Recommending improvements to national and international codes and standards.

Thank you.

Jay Johnson
Photovoltaic and Distributed Systems Integration
Sandia National Laboratories
P.O. Box 5800 MS1033
Albuquerque, NM 87185-1033
Phone: 505-284-9586
jjohns2@sandia.gov